BY HAROLD KINLEY

# The isolator: An RF traffic director

## It effectively blocks the return of reflected power when basic precautions are taken

An RF isolator keeps reflected power from returning to the transmitter output and keeps other signals from getting into the transmitter output. It also provides a good impedance match to the transmitter output. This article describes the basic RF isolator and how it is used.

Figure 1 shows a drawing of a typical RF isolator. It is a three-port device with an input port, an output port and a load port. For our purposes, there is little need to know the internal design of the RF isolator. Hence, the RF isolator will be treated as a black box in this discussion. As depicted by the solid arrow in Figure 1, the normal direction of RF flow is into the input port, through the isolator, and out of the output port. Any RF signal entering the output port is directed through the isolator to the load port where it is dissipated as heat in the dummy load. The dashed arrow in Figure 1 depicts the reverse RF flow.

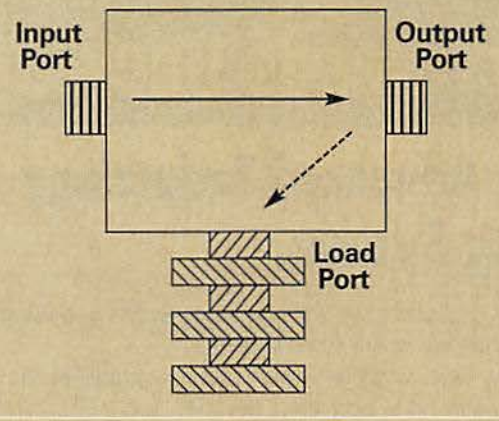


**Figure 1:** A typical single-section isolator is shown here. Normal RF flow is from the input port on the left to the output port on the right. Reflected power, indicated by the dashed arrow, is "dumped off" into the dummy load connected to the load port.

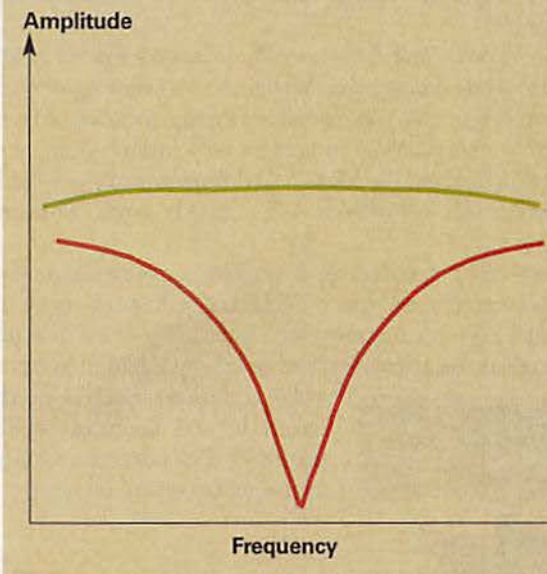


**Figure 2:** The response of the isolator in the forward direction is very broad. This is represented by the green response curve at the top. On the contrary, the response in the reverse direction (red curve) is comparatively narrow and maximum rejection appears at a single or narrow band of frequencies.

Figure 2 shows the typical response of the RF isolator in the forward and reverse direction. The response in the forward direction is very broad, offering little attenuation to a broad range of input frequencies. However, in the reverse direction, the response is relatively narrow. Maximum attenuation in the reverse direction occurs at a single frequency or a very narrow band of frequencies.

Using the black-box approach, let's examine the typical operation of a properly tuned isolator (Figure 3). An RF isolator is connected to (and physically located near) the output of the transmitter. The green arrow depicts the normal forward RF flow. The dashed red arrow depicts the reverse RF flow back into the isolator. This reverse flow could be reflected power from the antenna, extraneous signals picked up by the antenna, or both. The RF signal entering the output port of the isolator is dumped off into the dummy load at the load port. The dummy load then dissipates the returned power as heat.

Let's analyze the operation of an RF isolator by applying specific numbers to the setup shown in Figure 3. In this example, the transmitter RF output power is 100 W, the insertion loss of the isolator (in the forward direction) is

0.3 dB, and the transmission line loss is 1.5 dB at the operating frequency. Let's also establish that the SWR at the antenna is 3:1 while the isolation (reverse flow insertion loss) of the RF isolator is 30 dB. Because the isolator has an insertion loss of 0.3 dB in the forward direction, the output power is 93.3% of the input power to the isolator. Consequently, we are able to demonstrate in Equation 1 (on page 36) that the forward power at the output of the isolator is 93.3 W.

Table 1 shows the equivalent percentage of power for decibel losses from 0.1 to 1 dB. The forward power at the antenna can be calculated using Equation 1. Or the calculation can be done using the data from Table 1. Because the transmission line has a loss of 1.5 dB, we can use the multiplication factors of 1 dB and 0.5 dB in Table 1 to calculate the forward power at the antenna. In this case, the factor for 1 dB is 0.794 and for 0.5 dB is 0.891. Multiplying these two factors and then multiplying the result by the forward power at the isolator output yields forward power at the antenna of 66 W [0.794 x 0.891 x 93.3].

The next step is to calculate the reflected power from the antenna, which we do in Equation 2 (on page 36). Hence, the reflected power is 25% of the forward power, or 16.5 W [0.25 x 66 W]. The reflected power will incur the same 1.5 dB of line loss. Using Table 1 as before, we find the reflected power at the output port of the isolator to be 11.7 W [0.794 x 0.891 x 16.5 W]. If the internal loss between the output port and the load port is negligible, then the power applied to the dummy load will be approximately the same as the reflected power at the output port, or 11.7 W.

Because the isolation (reverse insertion loss) of the RF isolator is specified as 30 dB at the operating frequency, the reflected power appearing at the RF output of the transmitter will be 11.7 W minus 30 dB. Because a reduction of 10 dB represents a power multiplication factor of 0.1, then 30dB is a multiplication factor of 0.001. So the reflected power appearing at the transmitter output equals 11.7 mW [0.001 x 11.7 W = 0.0117 W]. Table 2 offers a handy chart for finding the equivalent power reduction for decibel losses. The net radiated power is the forward power at the antenna minus the reflected power at the antenna, or 49.5 W [66 W - 16.5 W].

**It is important to note that even under perfect load conditions at the output port of the isolator there will be some reflected power at the input port of the isolator due to a slight mismatch at the port.**

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**Figure 3:**

An RF isolator is connected to the output of the transmitter. The green arrow depicts the direction of normal forward RF flow. Any reflected power, depicted by the red dashed arrow, is returned to the isolator and "dumped" into the dummy load connected to the load port.

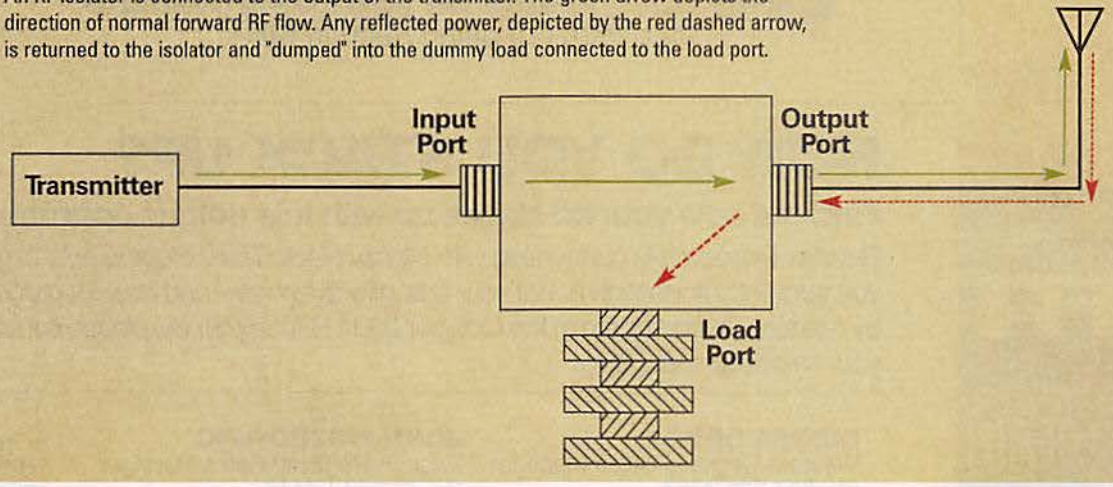
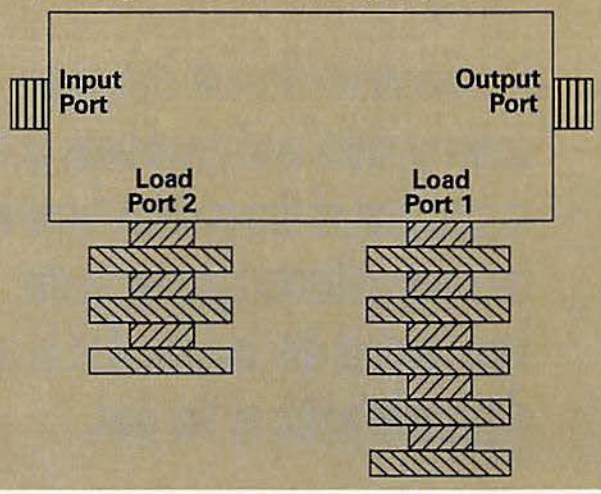


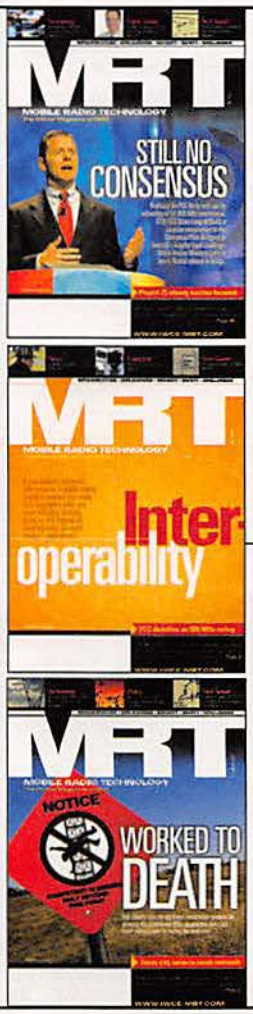
**Figure 4:**
A dual-section RF isolator is depicted here. The dual-section isolator has approximately twice the isolation of a comparable single isolator and twice the insertion loss in the forward direction. Notice that the dummy load connected to the load port nearest the output port is larger than the other dummy load. This is because this is the first load port that the reflected power sees and therefore is the first line of defense. Any power reflected from load port 1 is "seen" at load port 2. Generally, the dummy load at the first load port is rated at half the transmitter power. For a 100 W transmitter, the rating of the dummy load would typically be 50 W.




stated that the SWR at the input port is 1.15:1 or better. Assuming a worst-case of 1.15:1, the reflected power under perfect load conditions at the isolator output would be 0.4867 W or 486.7 mW.

The combination of both reflected powers, the reflected component caused by the mismatch at the antenna and the reflected component caused by the mismatch at the isolator input port, amounts to a difference of only 0.1 dB, approximately. Thus, the most significant contribution of reflected power, in this example, is caused by the isolator input port mismatch.

To further explore the significance of the input port mismatch, assume a worst-case mismatch at the output of the isolator, for instance a shorted connector attached to the isolator output port. As before, 100 W is applied to the input port. With a 0.3 dB insertion loss, 93.3 W appears at the output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port. With an isolation of 30 dB, the reflected power at the input port (caused by the mismatch at the output port) will be 0.0933 W or 93.3 mW. This is still much less than the reflected power caused by the mismatch at the input port and will increase the total reflected power seen at the transmitter by less than 1 dB. Note: the dummy load at the load port usually is not large enough to handle this amount of reflected power.

Of course, the above discussion is theoretical. In the real world things change a bit. First, there is the heat factor. The heating caused by normal operation can compromise the performance of the RF isolator. Excessive reflected power will increase the required load dissipation and increase the temperature of the isolator. Consequently, reflected power should be kept to a minimum. Even though the isolator prevents the transmitter from "seeing" most of the reflected power, the isolator is not an impedance matching device. This is worth repeating: the RF isolator is not an impedance matching device! Even so, the RF isolator provides an excellent 50-ohm load impedance to a transmitter.

**Even though the isolator prevents the transmitter from "seeing" most of the reflected power, the isolator is not an impedance matching device.**

Manufacturer's specifications and recommendations should be followed in order to ensure proper operation of the isolator. If the manufacturer states that the isolator should not be mounted on a ferrous metal surface, doing so might significantly detune the isolator and reduce the performance. Also, do not exceed the power input specification rating of the isolator. Power input should be reduced commensurately to keep reflected power at the load port within the limits of the dummy load.

Dual- and even triple-section isolators are available for even greater isolation (Figure 4). Single isolators can be

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placed in cascade to achieve higher isolation than afforded by a single isolator, but this requires more space and interconnecting cables. Better heat dissipation is one advantage of this configuration. Also, should a single isolator in the cascade fail, it can be replaced at less expense than replacing a dual- or triple-section isolator. Remember that while isolation figures increase, so too does the forward insertion loss with multiple sections or cascades.

Make sure adequate ventilation is provided, even if it means adding an external fan to cool the isolator. Sometimes, the dummy load can be placed away from the isolator via an interconnecting cable. This can reduce the heat near the isolator in the case of significant reflected power. The dummy load should be rated for at least half the transmitter power. For a 100 W transmitter, the dummy load should be rated for at least 50 W. For multi-section isolators, the dummy load connected to the first load port should be rated for at least 50% of the transmitter power output. The remaining loads can be much smaller since they don't see as much reflected power.

Be sure to follow the output of the isolator(s) with a second-harmonic filter. Do not place the isolator at the output of a transmitter combiner. Each individual transmitter should be followed with an isolator and harmonic filter. Isolators should be used as a matter of standard procedure in order to keep intermod-forming signals out of the transmitter output stage or to significantly reduce the level of intermod products from the transmitter. By using common sense and following manufacturers' recommendations and specifications, you can get maximum performance and life out of a well-built RF isolator. Next month we will look at field-tuning isolators using various techniques and equipment.

Until next time—stay tuned! ■

**Equation 1:**

$$P=10^{\left(\frac{-dB}{10}\right)}\times 100=10^{\left(\frac{-0.3}{10}\right)}\times 100=0.933\times 100=93.3\%$$

**Equation 2:**

$$R=\left(\frac{S-1}{S+1}\right)^2=\left(\frac{3-1}{3+1}\right)^2=\left(\frac{2}{4}\right)^2=(0.5)^2=0.25$$

where R is reflected power and S is SWR

**Table 1:**

| dB loss | Percent power |
|---|---|
| 0.1 | 97.7 |
| 0.2 | 95.5 |
| 0.3 | 93.3 |
| 0.4 | 91.2 |
| 0.5 | 89.1 |
| 0.6 | 87.1 |
| 0.7 | 85.1 |
| 0.8 | 83.2 |
| 0.9 | 81.3 |
| 1.0 | 79.4 |

**Table 2:**

| dB loss or isolation | Multiplication factor |
|---|---|
| 1 | 0.794 |
| 2 | 0.631 |
| 3 | 0.501 |
| 10 | 0.1 |

**By using common sense and following recommendations and specifications, you can get maximum performance and life out of a well-built RF isolator.**